PIT CRATER CHAINS IN CRATERS OF THE MOON NATIONAL MONUMENT AND PRESERVE, IDAHO, USA. Christian Klimczak[1] and Paul K. Byrne[2], [1]Structural Geology and Geomechanics Group, Department of Geology, University of Georgia, Athens, GA 30602 (klimczak@uga.edu), [2]Planetary Research Group, Department of Marine, Earth, and Atmospheric Sciences, North Carolina State University, Raleigh, NC 27612 (paul.byrne@ncsu.edu).

Introduction: Pit craters are quasi-circular depressions that form by collapse of material into subsurface voids. Although often applied specifically to volcanic landforms that lack a raised rim and from which lava has issued [1], this term has also been used more generally to describe collapse structures associated with lava tubes, magma chambers, volcanic eruptions, karstic dissolution, or fracturing and faulting processes [e.g., 2].

Pit craters are frequently aligned in linear chains, suggesting that their location and formation is structurally controlled. This inference is supported by observations of normal fault scarps paralleling the sides of numerous extraterrestrial pit chains [e.g., 2]. Indeed, a formational sequence for pit crater chains has been proposed, in which discrete pits coalesce into elongate depressions that may ultimately form long, scalloped troughs or even well-defined graben [2]. Pit crater chains are common on Earth [3], Mars [2], the Moon [4], and small Solar System bodies [5].

Analogue Site: To appraise a population of pit craters on Earth as analogues to extraterrestrial pits, we conducted field work at Craters of the Moon (CotM) National Monument and Preserve, situated in the Snake River Plain in central Idaho. The area hosts a series of late Pleistocene to Holocene basaltic lava flows [6] that erupted within a rift zone, the so-called Great Rift—an area of localized crustal extension about 70 km long and 10 km wide (**Figure 1a**). Volcanic activity here has produced cinder cones, small shield volcanoes, fissures, open cracks [6], explosion pits [7], and pit craters that all follow the ~north–northwest trend of the rift (**Figure 1a**).

Pit Crater Mapping Survey: Within a geographic information system (GIS), we performed a mapping survey of pit craters in CotM, recording the dimensions and distributions of 174 pit craters there. Pit diameters range from smaller than 5 m to as much as ~400 m (**Figure 1b**). This size range overlaps with the lower end of sizes found for pit craters at the Kilauea rift in Hawai‘i [3]. Further, CotM pit craters are substantially smaller than those on Mars and the Moon for which comparable measurements exist [2,4]. The mean aspect ratio (i.e., the short:long axis ratio) for CotM pit craters is 0.67, indicating that these landforms are elongate in plan view. This finding is consistent with our observation that some of the CotM pit craters have coalesced to form long and narrow scalloped troughs, but we find in our data no readily apparent correlation of pit crater aspect ratio with size.

Field Observations: We complemented our mapping survey with detailed field descriptions of select pit craters at key locations within the park. One pit crater chain near Yellowjacket Waterhole (**Figure 1c**) consists of six circular and elongate craters and trends ~northwest. The pit chain occurs atop a volcanic fissure bound on either side by small fractures. The pits themselves have an inverted conical morphology, and loose sand- to boulder-size blocks of rock that formed the overlying “roof” litter the pit floors. The roof blocks reveal the pronounced stratification of centimeter- to meter-thick lava flows that characterize the entire Preserve. Our field observations provide support for elliptical pit craters having coalesced from two or more discrete, near-circular pits (**Figure 1c**).

Another chain of pit craters is associated with a well-exposed volcanic fissure trending ~north–northwest that bisects the “King’s Bowl” (phreatic) explosion pit [7]. Here, pit crater outlines are irregular (**Figure 1d**), and individual pits are filled with roof blocks up to 5 m wide. Small fractures, some only a few centimeters across, bound the fissure symmetrically in a complex map pattern. All of these structures postdate the surrounding lavas, and appear associated with the flexure and collapse of the flows that constituted the roof. We observed no lavas emanating from these pits: all of their rims are unmodified by subsequent flows.

Outlook: Pit craters on Mars and the Moon are morphologically similar to those CotM structures we observed. The developmental sequence proposed for extraterrestrial pit craters [2] is supported by our observations of coalesced and fracture-bound pits. However, we also find that the formation of scalloped troughs from discrete pits at CotM represents a deformation continuum, which may be accommodated by structures too small to resolve even with the very high-resolution image data currently available for Mars and the Moon. Moreover, an open question remains regarding whether pit formation is driven by collapse from subsurface evacuation of lava, by crustal extension (as suggested by the similarity in strike of the Yellowjacket and Kings Bowl pit chains and the Great Rift itself), or by both processes together. Continued structural analyses of pit craters at sites such as Craters of the Moon will yield further insight

into the formation of this ubiquitous type of extraterrestrial landform.

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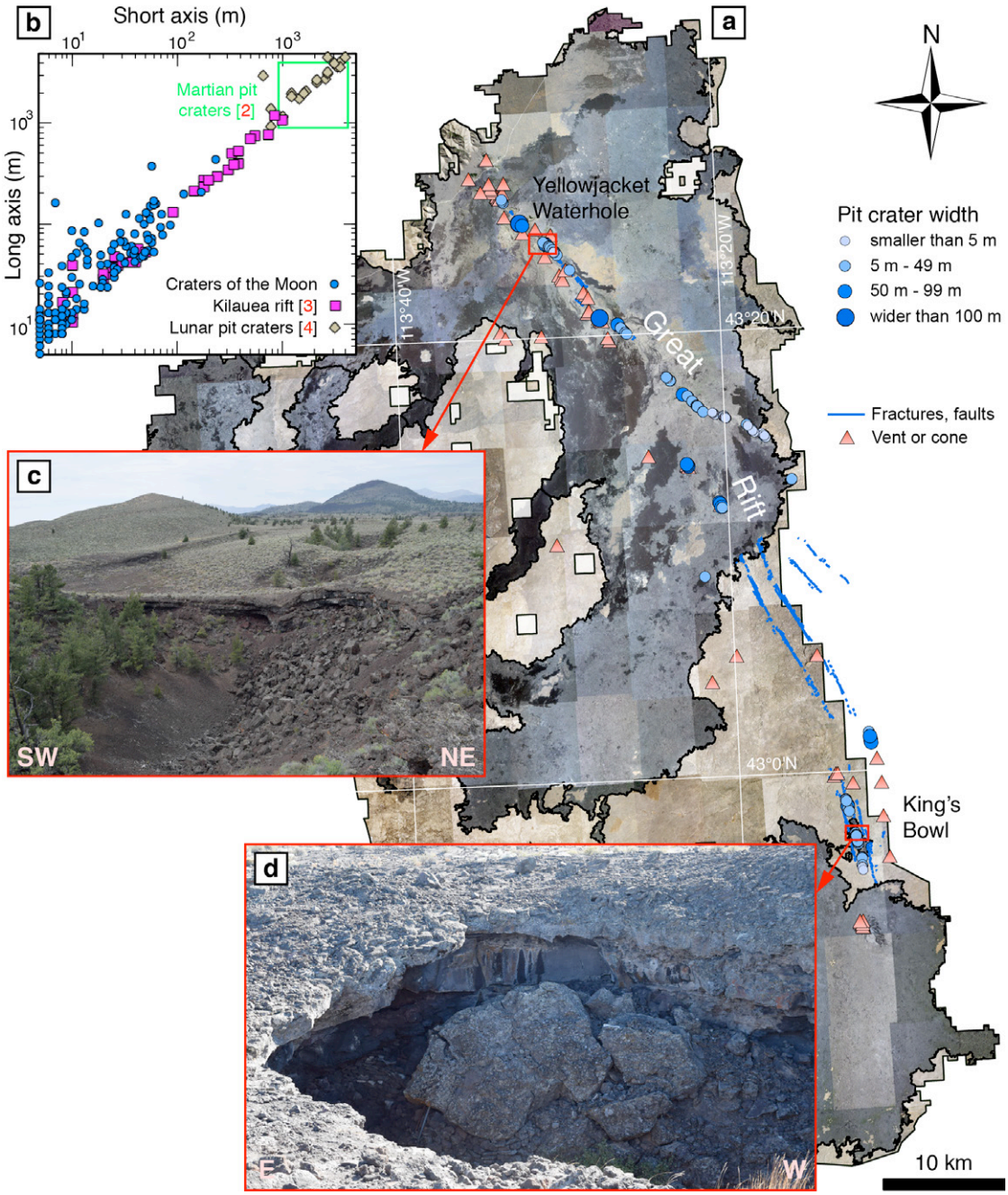

Figure 1. Volcanological landforms in Craters of the Moon National Monument and Preserve. **a.** Map showing location of pit craters, volcanic vents, cinder cones, and fractures associated with the Great Rift. **b.** Pit crater dimensions from this study (blue dots) shown with structures on Hawai‘i (magenta squares, after [3]), on Mars (green box, after [2]), and on the Moon (brown diamonds, after [4]). **c.** Pit crater chain showing three cone-shaped pits with sequence of lava flows at crater rim. **d.** Collapsed roof of pit crater revealing meter-scale thick lava flows.